Summary of the ILC Cryomodule Working Group Meeting Held at CERN

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OUTLINE

- Some general meeting information
- Format of meeting
- Meeting goals and details:
  - Organizational
  - Technical
- Interactions
- Conclusions

General

- Meeting Agenda:
  - Monday, January 16
    - Introduction and meeting overview — H. Carter
    - Organizational issues — H. Carter
    - Institutional Participation — Inst. Representatives
    - Lunch
    - Technical Discussions — D. Mitchell, T. Peterson
  - Tuesday, January 17
    - Technical Discussions — T. Peterson
    - Lunch
    - Continuation of Technical Discussions — T. Peterson
    - Summary Review — H. Carter
    - Next meeting
    - Adjourn

General

- Presentations, task lists, and reference information for the working group discussions can be found at the following URL:

  http://indico.cern.ch/conferenceDisplay.py?confId=671

Meeting Format

- What the meeting was:
  - A working group meeting to discuss the next generation cryomodule (Type IV or T4CM)
- What the meeting was not:
  - A workshop---there were very few formal presentations and no invited talks

General: Meeting Attendees (25 persons; 9 Institutions)

Name	Institution	E-mail	Comments
Bob Kephart	FERMILAB	kephart@fnal.gov	
Shekhar Mishra	FERMILAB	mishra@fnal.gov	
Harry Carter	FERMILAB	hfcarter@fnal.gov	
Tom Peterson	FERMILAB	tommy@fnal.gov	
Don Mitchell	FERMILAB	dmitchel@fnal.gov	
Rao Ganni	JLAB	ganni@jlab.org	
Joe Preble	JLAB	preble@jlab.org	
Mark Wiseman	JLAB	wiseman@jlab.org	
Rolf Lange	DESY	rolf.lange@desy.de	
Kay Jensch	DESY	kay.jensch@desy.de	
Chris Adolphsen	SLAC	star@slac.standard.edu	
John Weisend	SLAC	weisend@slac.stanford.edu	
Norihito Ohuchi	KEK	norihito.ohuchi@kek.jp	
Carlo Pagani	INFN Milano	carlo.pagani@mi.infn.it	
Paolo Pierini	INFN Milano	paolo.pierini@mi.infn.it	
Nicola Panzeri	INFN Milano	nicola.panzeri@mi.infn.it	
Franco Bedeschi	INFN Pisa	franco.bedeschi@pi.infn.it	
Fabrizio Raffaelli	INFN Pisa	fabrizio.raffaelli@pi.infn.it	
Andrea Basti	INFN Pisa	andrea.basti@pi.infn.it	
Bernard Rousselet	CEA Grenoble	brousset@cea.fr	day 2 only
Laurent Tavian	CERN	laurent.tavian@cern.ch	part of time
Vittorio Parma	CERN	vittorio.parma@cern.ch	
Cedric Garion	CERN	cedric.garion@cern.ch	part of time
Stefano Sgobba	CERN	stefano.sgobba@cern.ch	part of time
Gilles Favre	CERN	gilles.favre@cern.ch	part of time

The path to this point

- 1st Cryomodule meeting at SLAC (Oct. 2004)
  - working group formed to begin identifying the “next generation” cryomodule design issues
- 2nd Cryomodule meeting at the SMTF Collaboration meeting at Fermilab (Oct. 2005)
  - continued working group discussion of features to be incorporated in T4CM
  - created rough estimate of the time required to complete the T4CM design
- Other relevant meetings----Snowmass 2005 and the recent Frascati meeting

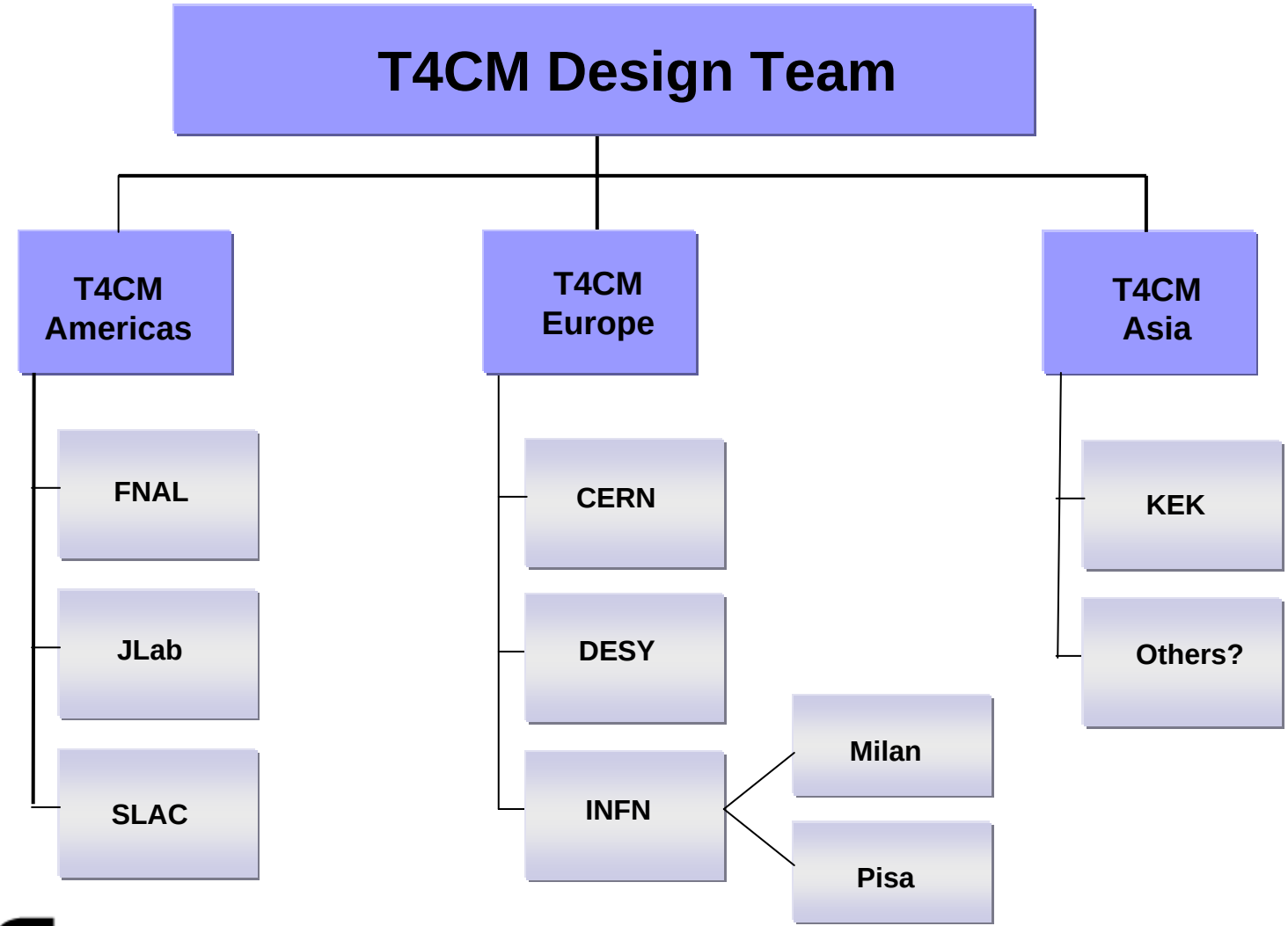
Goals for the meeting were:

- Formation of an international T4CM design team
  - This did not mean a “design by committee”
- Definition of what a T4CM is
  - What items are incorporated from the possibilities
- Identification of a comprehensive list of tasks to be accomplished
- Creation of work packages to address tasks
- Assignment of work packages to T4CM design team members
- Establish a timeline for T4CM design completion

Organizational Issues

- Design team formation
  - Regional structure and leadership
    - Sort of a “mini-GDE” structure
    - Need to identify regional leader(s)
- Design tools, standards, and data exchange
  - Should design tools be common or regional in nature?
  - What design standard(s) should be used?
    - Example: Type III+ cryomodule vs. FNAL design requirements
  - What format should be used for data exchange?
- Integration issues
  - to be coordinated by regional leadership
  - information exchange

International Design Team Formation (Proposal)



Institutional Participation in T4CM

- At this point representatives from each institution (listed below) were invited to give brief presentations: the order was be alphabetical, except I presented Fermilab's plan last:

CERN	V. Parma
DESY	R. Lange
INFN Milan	C. Pagani
INFN Pisa	F. Bedeschi
JLAB	J. Preble
KEK	N. Ohuchi
SLAC	J. Weisend
FNAL	H. Carter

Speakers were asked to address:
- **institutional resources**
- **resource availability**
- **tasks which they are interested in working on**

Institutional Participation in T4CM

- CERN: V. Parma stated that the majority of the CERN ILC effort would remain concentrated on the cryogenic systems design effort. He did volunteer some of his time to look at the cryomodule interconnection area, based on his experience with LHC interconnects.

- DESY: R. Lange stated that as the SRF cryomodule seat of knowledge for 1.3GHz cryomodules, DESY's future role in ILC cryomodule development will be one of consultation and knowledge transfer to those directly working on the new generation designs. Of course, the primary role of DESY in the future will be the XFEL project. Claudia Engling is developing a full 3-D model of the Type III+ cryomodule, which will be available shortly. A portion of TTF operations (up to 30%) may be devoted to ILC studies.

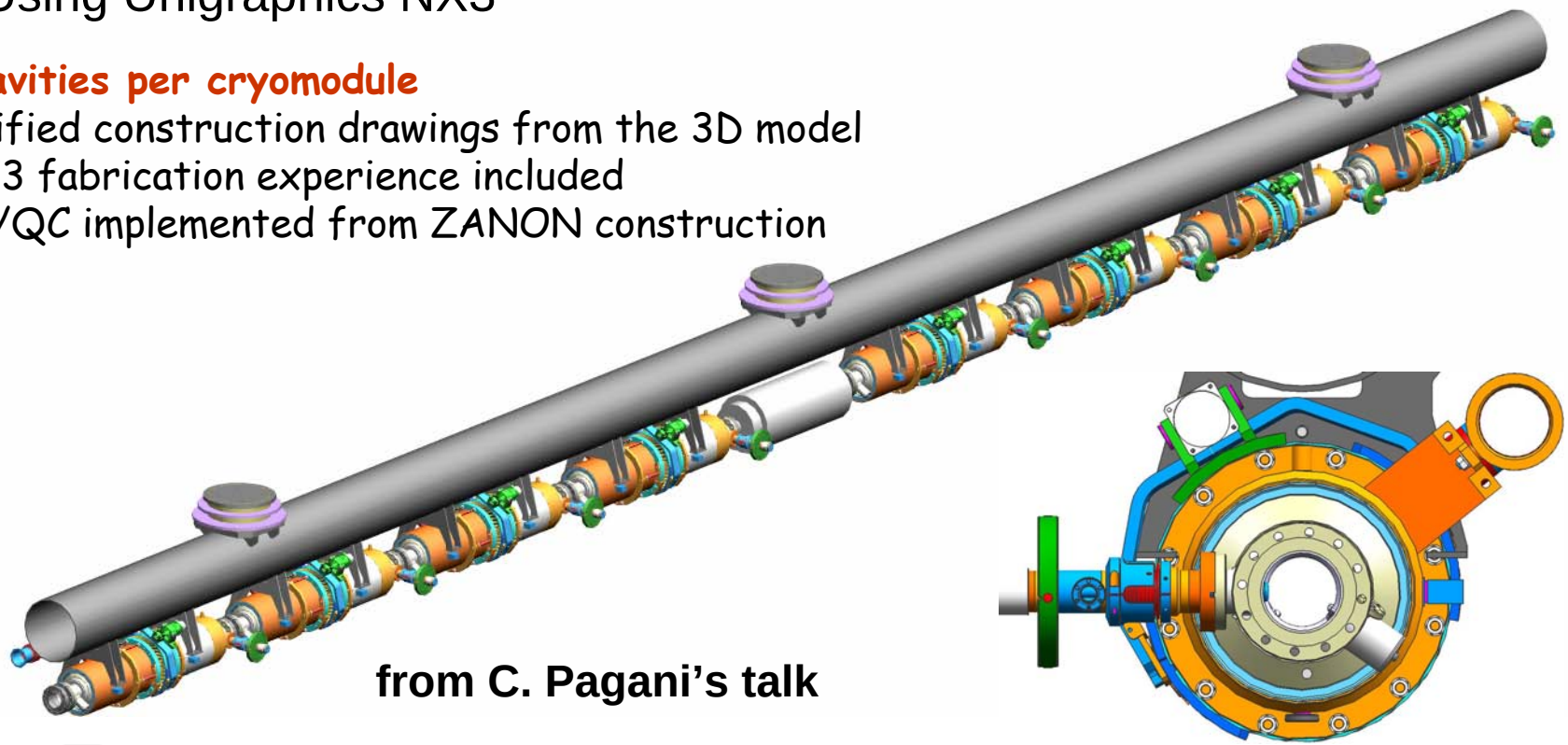
Institutional Participation in T4CM

- INFN-Milan: C. Pagani
  - He and his team have already begun a T4CM solid model based on their experience with the Type III and III+ designs (see next slide)
  - He expects that he can have documentation and fabrication drawings by end 2006

3D Parametric Model well advanced

- Starting from “original” INFN CRY3 AutoCAD DWGs used for all modules fabrication
- Rebuilding a CRY3 with “symmetric” quasi TESLA TDR string (8)
- Using Unigraphics NX3

- **8 cavities per cryomodule**
- Verified construction drawings from the 3D model
- CRY3 fabrication experience included
- QA/QC implemented from ZANON construction



from C. Pagani’s talk

Institutional Participation in T4CM

INFN-Pisa: F. Bedeschi

- As the CMS work they are presently engaged in starts to wind down in approximately four months, INFN-Pisa is very interested beginning SRF cryomodule work.

See next 3 slides

INFN-Pisa: General goals (1)

- Long term goals:
  - Major participation in the design and construction of the ILC cryomodules and their control systems (WPM, Piezo control, LLRF)
  - Establish R&D program with Italian industries to prepare for future participation in mass production of mechanical and electronic parts
  - Contribute to commissioning of cryomodule test facilities

INFN-Pisa: General goals (2)

- Short term goals (mechanics only)
  - Improve current existing cryomodule design in close cooperation with the INFN-Milan group
    - Imported parametric 3-D model with central quadrupole package from Milan
    - Started calculations on various aspects of this design
    - Aim to have updated design by end of 2006
  - Cryomodule mockup construction in Pisa
  - Participate in monitoring of cryomodule construction at Zanon this spring

Manpower at INFN-Pisa

- Situation for mechanical work on cryomodules
  - 3 Physicists
  - 2 staff engineers
  - 2 young engineers
  - 1 designer
- Current involvement ~ 20% for most people
  - Growing during 2006 as other activities ramp down
- Good support from INFN
  - Expect manpower to grow if needed

Institutional Participation in T4CM

- JLAB: J. Preble
  - Emphasized cryomodule experience on
    - SNS – five year project
    - CEBAF, including three upgrade cryomodules
  - Expressed Further Areas of ILC interest
    - Cavity development, design, and optimization
    - Cavity manufacturing and processing
    - Tuners, slow and fast
    - Manufacturing and assembly, industrialization
    - System integration
      - Cryogenic, RF and controls, interlocks…

Institutional Participation in T4CM

- KEK: N. Ohuchi stated that they will continue their plans for their four-cavity cryomodule development for Phases I and II for the STF. This cryomodule is meant to be a cavity test vessel rather than an ILC cryomodule. As they begin Phase II, they will be more interested in the T4CM design effort, but in the interim, they will collaborate on areas of common interest including couplers, tuners, and cavity processing.

Institutional Participation in T4CM

- SLAC: J. Weisend
  - Staff resources
    - 1 – 2 cryogenic engineers
    - 0.5 designers
    - Technicians for construction and operation of cryogenic experiments
    - Physicists and technicians for designing and conducting precise magnetic measurements
    - Physicists, engineers & technicians for designing and testing prototype beam line components

Institutional Participation in T4CM

- SLAC: J. Weisend
  - Facilities
    - Precision magnetic measurements lab
    - Currently being upgraded to allow testing of superconducting magnets
    - Cryogenics lab for small scale tests of components (current leads, supports, small magnets etc)
    - Up to 1 kW of 4.5 K refrigeration available
    - Some He II capacity. Much more could be provided via a straightforward upgrade
    - End Station A allows beam tests of prototype ILC components.
    - Testing at 4.2 K possible now.
    - Testing at He II temperatures is possible if additional upgrades are made.
    - Strong capabilities in research support (safety, rigging, instrumentation, DAQ, alignment etc)

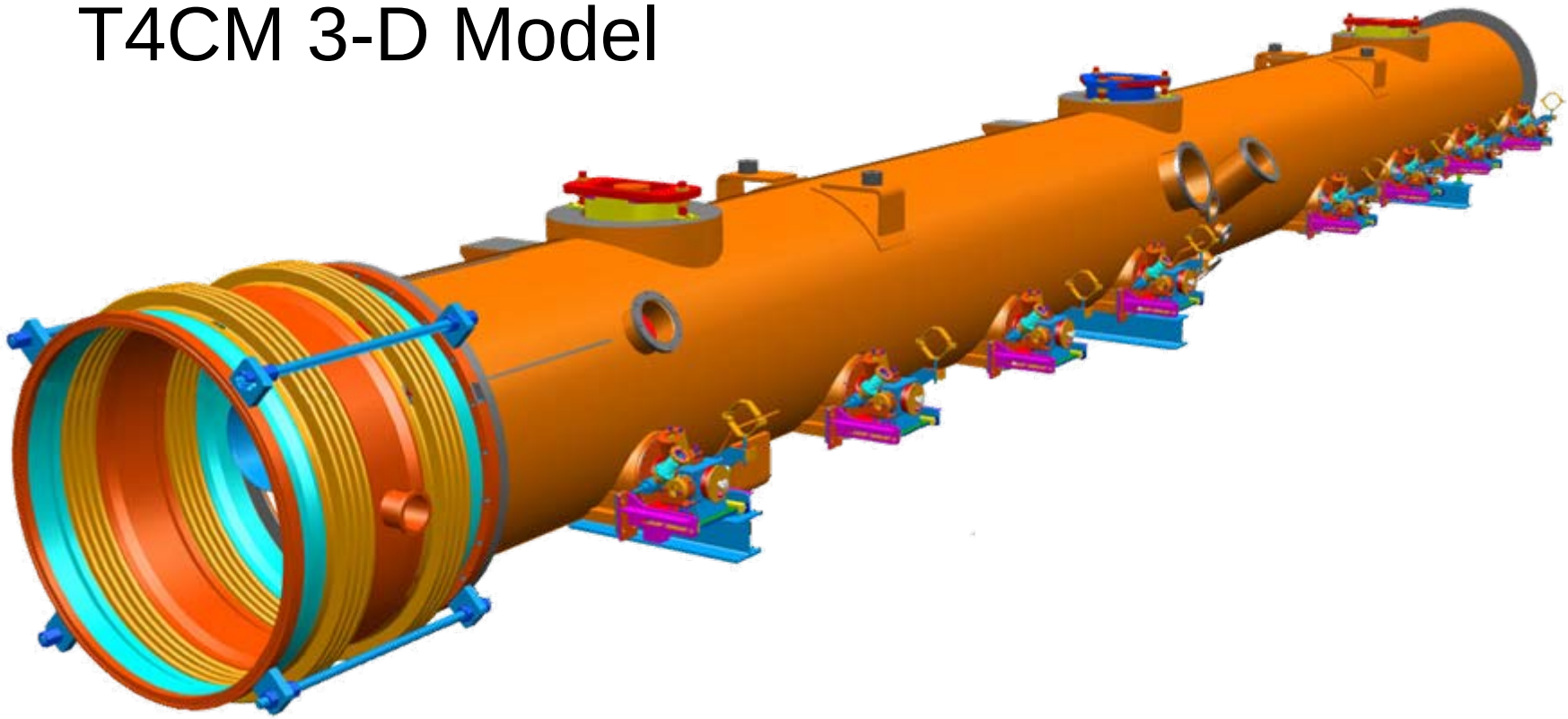
ILC Americas T4CM Design Team

- **Task Manager:** **T. Peterson**
  - Task Engineering:
    - D. Mitchell: Mechanical design
    - T. Nicol: Cryostat & supports
    - M. McGee: Vibration measurement & analysis
    - S. Tariq: FEA analysis of mechanical components (tuners,cavities, etc.)
    - J. Tompkins: SC quadrupole & correctors
    - V. Kashikin: SC quadrupole & correctors
    - J. Weisend: Cryostat & cryogenics
    - K. Jobe: Cryostat & cryogenics
  - Task Designer(s): Contract Designers
  - Task Scientific Input: H. Edwards / S. Mishra/ K. Ranjan/ N. Solyak/ Paul Lebrun / H. Padamsee

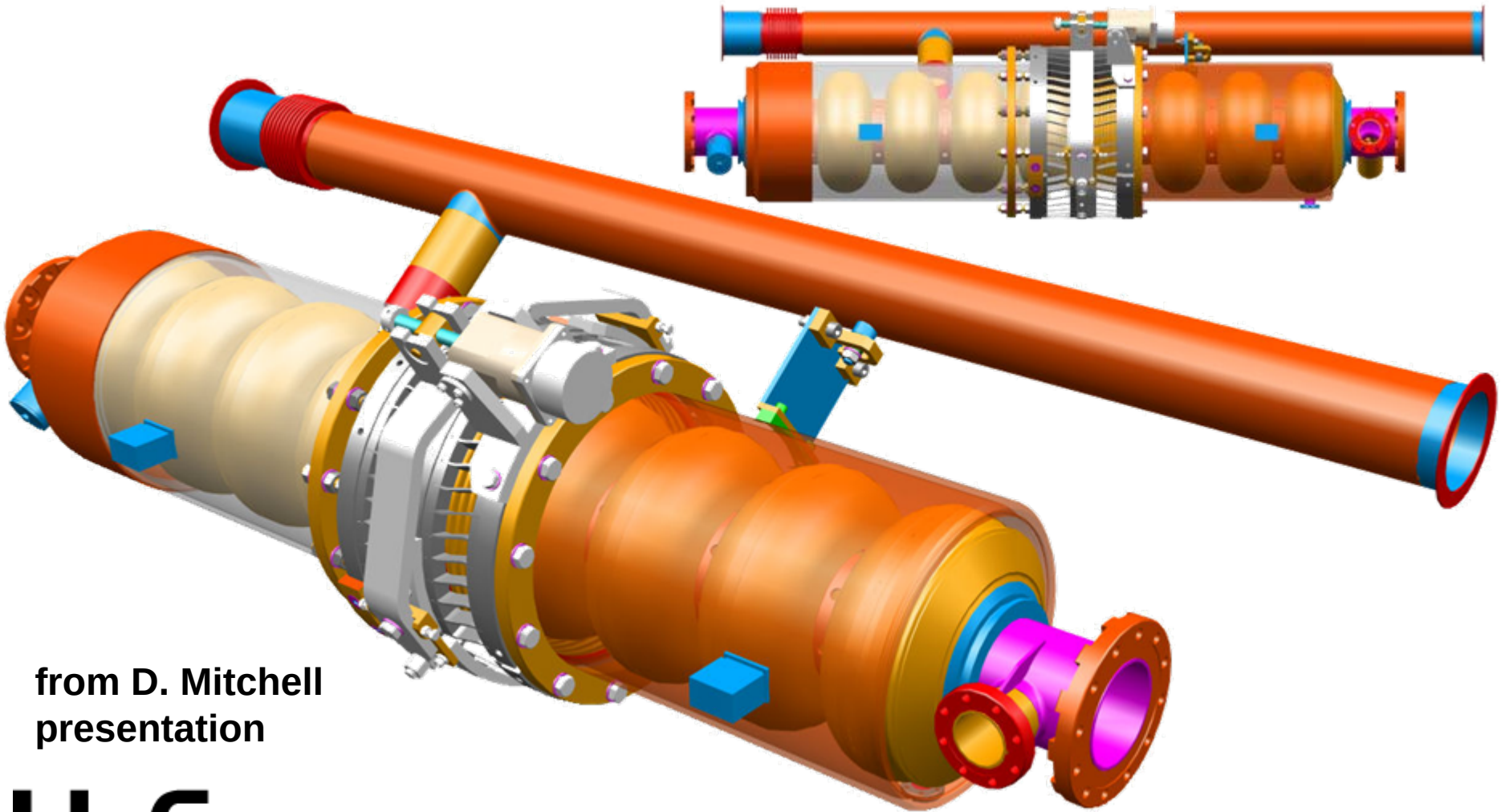
Deliverable: Complete T4CM drawing package ready for procurement by end of CY07

Technical Details

- Don Mitchell Presented a Conceptual T4CM 3-D Model

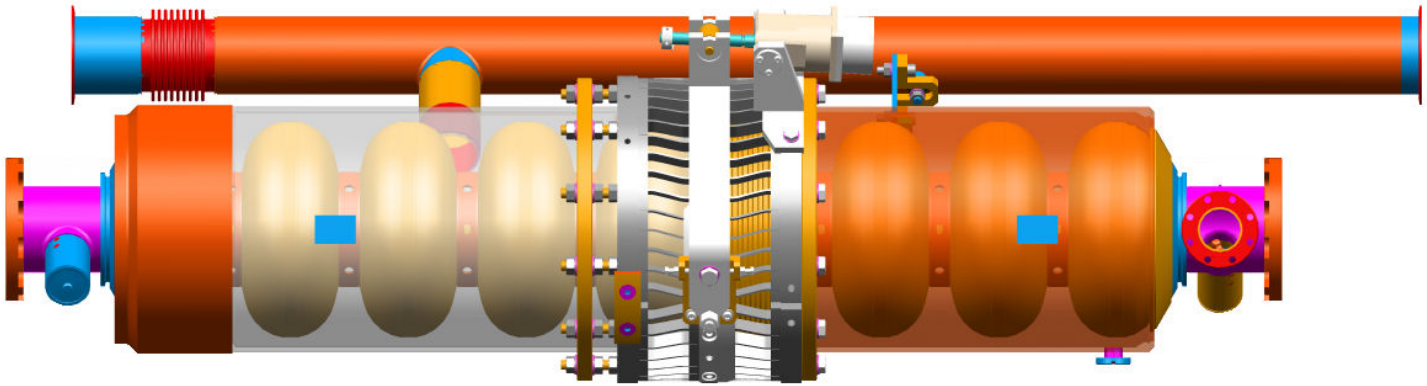


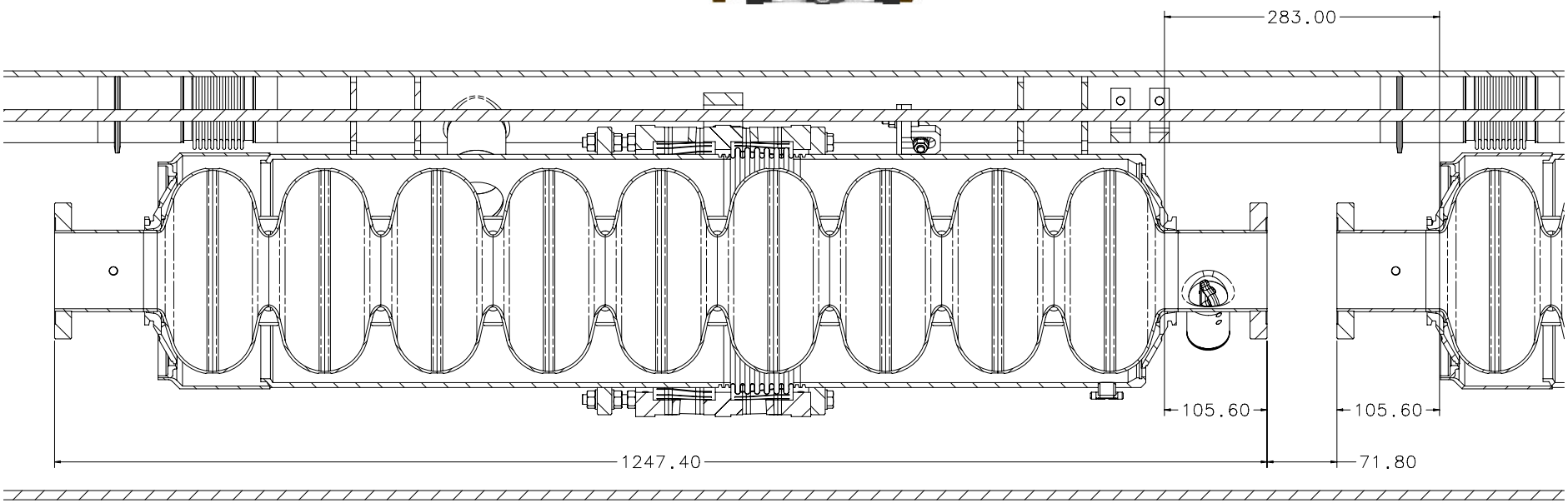
T4CM Proposed Cavity w/ Bladetuner



from D. Mitchell presentation

Cavity Dimensions





Technical Details

- Tom Peterson led the T4CM Task List Discussion supplemented by a comprehensive 100-slide presentation
- The task list is presented in the next few slides

T4CM Task List

1. **Begin a type IV 3-D model and drawing set by importing those features that will remain the same as type III+.** Type IV cryomodule will include the following features from Type III+ :
   - Same vacuum vessel diameter and cavity centerline location
   - Same support posts
   - Same cavity support detail (with roller bearings and invar rods)
   - Same input coupler (Type III/XFEL) at least in terms of mounting and interface to vacuum vessel, cavity, and thermal shields
   - **Who:** KEK, DESY, Fermilab, INFN. Parallel efforts to obtain consistent model

2. **Decide on pressure drop criteria and pipe sizes for the modules.** Thermal shield pipe sizes increase to accommodate high flows and long spacing. Evaluate in conjunction with the development of a cryogenic system layout.
   - **Who:** CERN, Fermilab, DESY

3. **Design of a segmentation "spool" piece.** Segmentation of the cryomodule strings, or some other means by which to enable warming up of relatively short sections of the linac.
   - **Who**: SLAC, Weisend; Fermilab, Klebaner

T4CM Task List

4. **Design the intercavity connecting flange and bolting arrangement, detail the new spacing.** Cavity iris-to-iris spacing reduced to 283 mm. This is ongoing work but has been moving slowly due to limited resources. Salman Tariq has some confidence that modifying the existing design will work, but it would also be worthwhile to begin exploring quick disconnect options. By late summer next year, we hope to have the modified design analyzed and a prototype built & tested. Getting another engineer involved to look at quick disconnect options might be worthwhile.
   - **Who:** KEK, (Jlab), CERN, INFN, Fermilab

5. **Modify the slow tuner design to allow closer cavity-to-cavity spacing, integrate with fast tuner effort** Could mean switching to blade tuner design. Could have a few parallel tuner efforts with a later selection of the tuner. Tuner motor reliability, replacement, repair or location (warm, cold intermediate, accessible, etc.) is an issue for review. Salman Tariq: "We have been conducting an extensive R&D effort on slow/fast tuning utilizing Capture Cavity 2 and Saclay lateral tuner, hoping to understand as much as we can about the system. Several individuals have been involved from both TD & AD."
   - **Who:** INFN, Fermilab, KEKType IV coaxial tuner

T4CM Task List

6. **Modify the fast tuner design for proper piezo function**Also consider modifications to the design for magnetostrictive fast tuner. Salman Tariq: "We have made decent headway and are working towards studies incorporating magnetostrictive actuators."
   - **Who:** INFN, KEK

7. **Design the support details for locating quad/corrector/BPM package under center post, but still hung from 300 mm tube**The quad/corrector/BPM package is a major unknown right now, we need information. Could have some parallel quad support concepts under development by different groups for later selection. Also consider external support location impact on quad/BPM alignment.
   - **Who:** INFN, Fermilab, KEKPart of the parallel modeling efforts

8. **Select some possible quadrupole current leads and work out configurations for integration into module.** The quad current leads may be new and different from TTF type III, with local impact on thermal shields and vacuum vessel ports, and we need provisions for quad power lead connection.
   - **Who:** CERN, Fermilab, KEK

9. **Vibrational analysis of the quad and cavity support structure.** Analyses should be compared to measurements for verification of the model for future design work.
   - **Who:** INFN, Fermilab

T4CM Task List

10. **Design for stability with shipping, analysis of shipping restraints and loads.** Need to define shipping methods and requirements.
    - **Who:** DESY, Fermilab

11. **Active mover design.** The task could start with an attempt to determine the need (or not) and specification for active movers. However, I (Peterson) do not believe we will incorporate active movers in Type IV.
    - Yes, longer-term parallel effort

12. **Conceptual design of separate quad cryostat.** An alternative, not part of the baseline type IV configuration, but it offers some advantages for standardizing modules and flexibility with respect to quad package variations and quad alignment.
    - **Who:** Fermilab Nicol; Longer-term

13. **Design module end to accommodate the input coupler at the far end of the cryostat.** All modules through type III+ included a quadrupole on the input coupler end of the last module. Without the quad, the last input coupler interferes with the vacuum flange. Some extra module length may be necessary.
    - **Who:** INFN, Fermilab. Parallel efforts, part of modeling effort.

T4CM Task List

14. **Module-to-module interconnect design.** The interconnect must include the 2-phase pipe to 300 mm pipe cross-connect and an HOM absorber on the beam pipe. We want minimum length in order to maximize linac packing factor.
    - **Who:** CERN, INFN, Fermilab, Part of modeling effort with input from CERN,

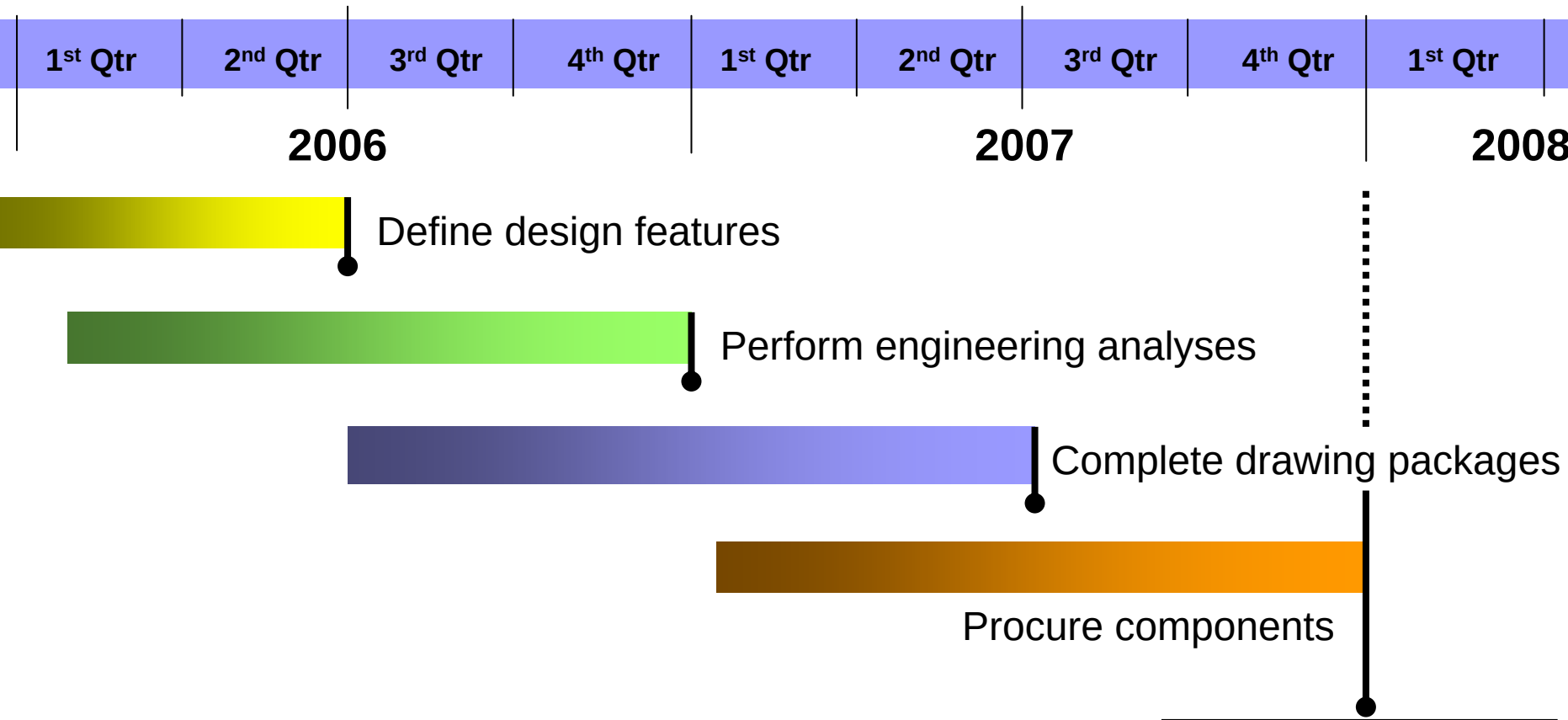
15. **Module slot lengths**Need to define a set of module slot lengths (with and without quad as a minimum) for the GDE RDR effort. This is a "bottom line" based on preliminary estimates for many of the above numbers.
    - **Who:** INFN, Fermilab. Outcome of modeling effort.

16. **Develop module test plans and module component test plans.** Consider not only what must be done on a module test stand, but also what earlier tests of the module and module components should be done for QA, QC, and understanding module performance.
    - **Who:** DESY (XFEL), and all

T4CM Task List

17. **Design of instrumentation for installation into the module.** Wire position monitor details or another system to verify cavity positional stability with thermal cycles, thermometry, etc.
    - **Who:** DESY (XFEL), and all
18. **Magnetic shielding.** Review present practices, make changes to incorporate blade tuner design. Explore alternate concepts such as internal helium vessel shield proposed by KEK.
    - **Who:** KEK, DESY, and all

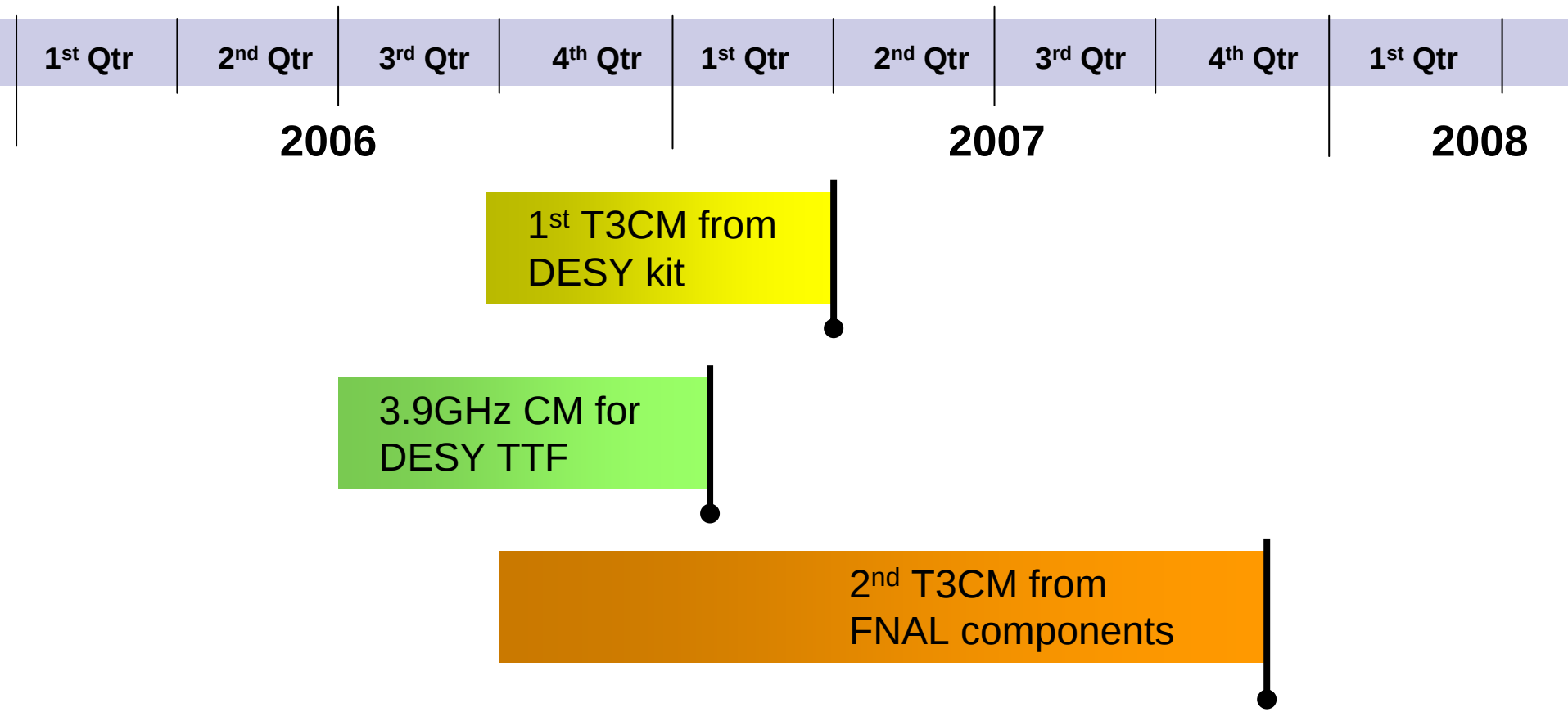
Arriving at a T4CM Design



Who will build the T4CM?

- FNAL plans:
  - The third cryomodule to be assembled at Fermilab will be a T4CM design, incorporating a quadrupole/BPM package if one is available at the start of construction, otherwise a predetermined space will be left for this package and an instrumented mockup (correct size and weight) will be installed.

Schedule for CM Assembly at FNAL



Who will build the T4CM?

- DESY plans:
  - The next cryomodule to be assembled at DESY will be a Type III+ design, designated Cryomodule #6, and will contain 8 cavities with accelerating gradients of $\geq$ 35MV/m.
  - After Cryomodule 6, a spare Type II cryo-module for TTF, designated Cryomodule #7, will be assembled, then the “kit” for the first FNAL cryomodule will be assembled

Who will build the T4CM?

- KEK plans:
  - Phase 1: KEK is currently working on a cryomodule design that they plan to assemble at KEK in 2006. This cryomodule will contain 4 cavities of the low loss design with accelerating gradients of $\geq$ 35MV/m.
  - Phase 2: Two such cryomodules are planned to be built, joined together, and tested.

BCD Cryomodule:

- The T4CM rather than the Type III+ cryo-module has become the design adopted in the BCD:
  - 283 mm cavity-to-cavity spacing
  - coaxial slow tuner design
  - quadrupole in center of an 8-cavity cryomodule
- Main linac quadrupole spacing
  - 32 cavities per quadrupole (24 recommended by WG1)

BCD: Cryomodule configuration

Baseline

10MW klystron drives 24 TESLA cavities.

considering 7% WG loss and 11% overhead for 35MV/m operation

Cavities divided into three cryomodules,

Quad package in every 4th cryomodule,

Cos(2ϕ)type Quad + corrector windings+BPM,
supported from GRP at center post,
<u><10μm bunch-to-bunch resolution BPM</u>

Cavity spacing 283mm

Contradiction with GG2-BCD!

this slide taken from H. Hayano's talk "BCD Input from WG2"

ACD: Cryomodule configuration

Alternatives

- 12 cavities in one cryomodule,
- Cavity spacing 250mm~180mm,
- HOM readout,
- Quad-BPM in separate cryostat,
- Putting movers on center support post and cryomodule support,
- Reduce Quad aperture to ~35mm,
- 1μm resolution BPM

this slide taken from H. Hayano's talk "BCD Input from WG2"

General Interactions

- Critical items for other linac work to proceed
  - cavity length
  - cavity-to-cavity spacing
  - Quadrupole/corrector/BPM package design
  - overall cryomodule length:
    - required in order to define main linac layout for lattice considerations
    - required to define civil construction and cryogenic system requirements

Interactions: ILC Linac Layout

- Per request from Chris Adolphsen:
  - One of the goals of the GDE meeting at KEK on Jan 19-20 is to better define the ILC linac layout. To this end, we have been asked to provide working assumptions as to:
    - 1) the length of cryomodules with and without quads
      2) the external support of cryomodules (e.g. from the floor or ceiling)
      3) beamline and insulating vacuum segmentation
      4) cryogenic maintenance length and the additional space required between segments
      5) the space required to convert from cold to warm sections
      6) the refrigerator spacing, capacities and space requirements

We answered most of these items at this meeting but not all could be answered at that time

Interactions: Additional goals from Chris Adolphsen---

RDR module and cryosystem definition

- Length of cryomodules with and without quads
  - Answer: 12565 mm with a quad and 11271 without a quad
- External support of cryomodules (e.g. from the floor or ceiling)
  - Answer: from the floor until forced otherwise
- Beamline and insulating vacuum segmentation
  - Answer: segmentation box every 500 meters
- Cryogenic maintenance length and the additional space required between segments
  - Asnwer: segmentation box of one module slot length every 500 m
- Space required to convert from cold to warm sections
  - Answer: 1.5 meter transition
- Refrigerator spacing, capacities and space requirements
  - Results to come from cryogenic system effort

from Tom Peterson's presentation

Interactions in support of RDR effort

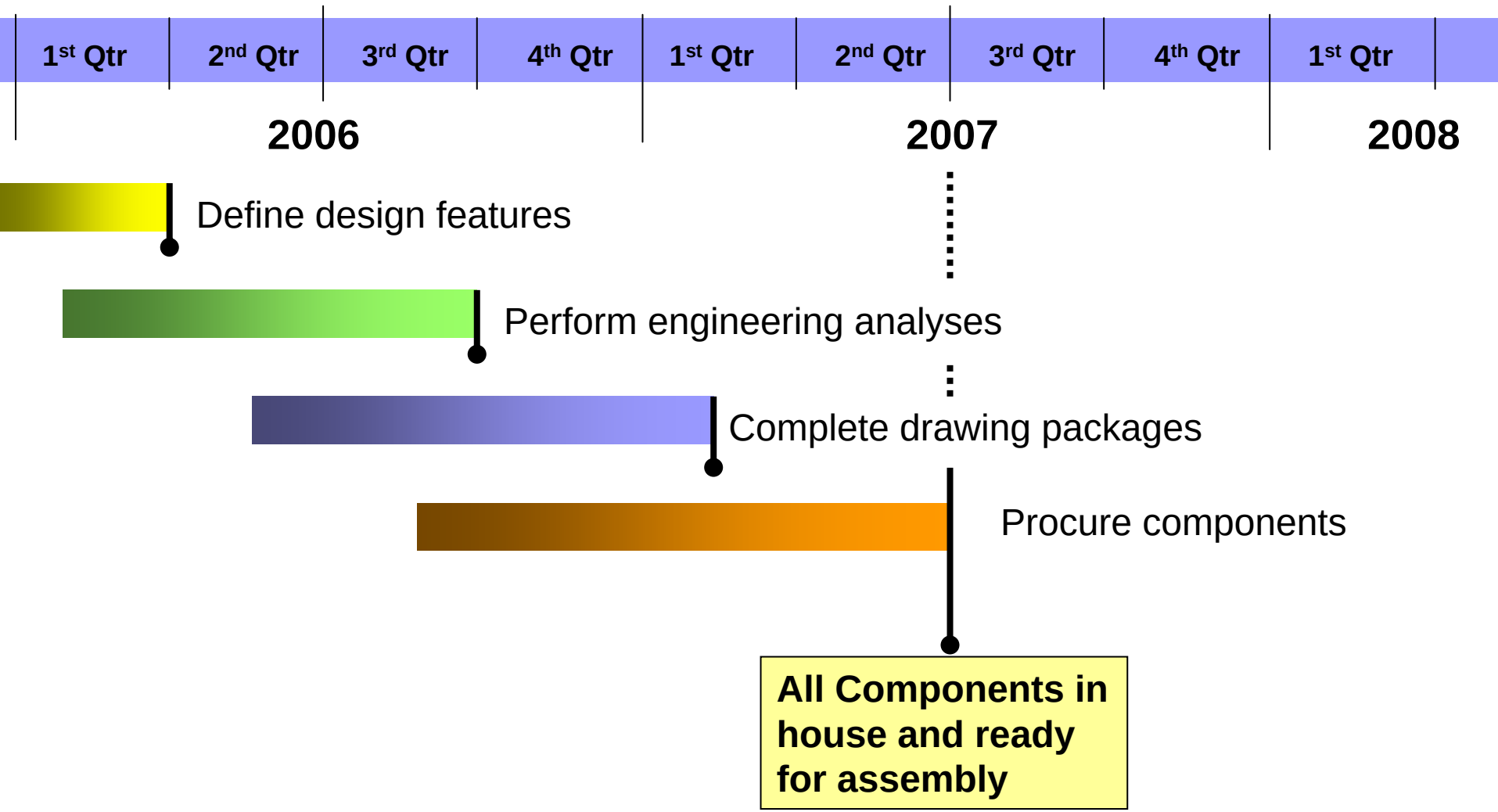
- RTML: P. Tenebaum has requested coordination of our efforts with the Ring-To-Main-Linac efforts. He states that the
  - RTML includes 4 cryomodules in its first-stage bunch compressor (BC1) and 57 cryomodules in its second-stage compressor (BC2), for a total of 61 modules per side (e^- side and e^+ side)
  - RTML cryomodules do not need to be operated at 31.5 MV/m, but will be standard main linac cryomodules that are always run at lower gradients
  - Possibility of one or two crab cavity cryomodules per side for beam diagnostics and other longitudinal diagnostics

Interactions in support of RDR effort

- BDS: A. Seryi has requested information in support of the crab cavity for the Beam Delivery System
  - The crab-cavity is the only SCRF cryomodule in the BDS
  - Basic parameters of the crab-cavity are given in BCD. We believe that the crab-cavity will be based on Fermilab CKM 3.9GHz deflecting cavity, however, design may be reoptimized.
- Work needed to be done includes:
  - Defining specifications for the crab-cavity
  - Developing the design for the RDR
  - Producing the cost estimates.

Crab cavities are not a topic of discussion for this meeting however I include this request in case someone here is interested on working on this problem.

Arriving at a T4CM Design (Revised)



Conclusions: Did We Achieve the Goals for this Meeting?

- **Formation of an international T4CM design team**
  - Not exactly---
    - But we have identified broad institutional interest in participation
    - Is an international team approach the right organizational model for this effort?
    - Do we need to establish regional coordinators ?
    - Should we only have discrete work packages with one coordinator/integrator?
- **Definition of what a T4CM is**
  - Yes, we agreed that at the very least, the T4CM should include the following features:
    - 283mm cavity iris-to-iris spacing
    - quadrupole in the center of the cryomodule beneath the center support post
    - the space alloted for the quad/corrector/bpm package is 1200mm
    - coaxial tuner

Conclusions: Did We Achieve the Goals for this Meeting?

- **Identification of a comprehensive list of tasks to be accomplished**
  - Yes
- **Creation of work packages to address tasks**
  - Need to define scope of work for each task in order to create work packages
- **Assignment of work packages to T4CM design team members**
  - Not assignment at this time, but rather expressions of interest by institutions
- **Establish a timeline for T4CM design completion**
  - Not a firm timeline---a range of 12-24 months is still anticipated

Conclusions:

- **Future Meetings**
  - We agreed that we need to establish video conferencing as soon as possible in order to coordinate efforts on tasks
  - The next face-to-face meeting will be after the Bangalore GDE meeting
- **Summary**
  - In all, this was a very useful meeting
  - We still have a lot of work to do, but we have a plan for accomplishing this work
  - We need to follow up quickly to establish the work packages in order to capitalize on the forward momentum this meeting generated